

Water Rock Interaction [WRI 14]

Geochemistry and travertine dating provide new insights into the hydrogeology of the Great Artesian Basin, South Australia

A.J. Love^{a,*}, P. Shand^{a,b,c}, K. Karlstrom^d, L. Crossey^d, P. Rousseau-Gueutin^a,
S. Priestley^a, D. Wholing^e, S. Fulton^f, M. Keppel^a

^a*School of Environment, Flinders University, and NCGRT Adelaide, Australia*

^b*CSIRO Land & Water, PMB2, Glen Osmond, SA 5064, Australia*

^c*Adelaide Acid Sulfate Soils Centre, Adelaide University, Adelaide, South Australia*

^d*University of New Mexico, Albuquerque, New Mexico, USA*

^e*DEWNR, South Australia Government, Australia*

^f*NRETAS, Northern Territory Government, Australia*

Abstract

While of great national and societal significance, and importance in its own right, the Great Artesian Basin of Australia is an iconic example of a continental scale artesian groundwater system. New geochemical, hydrological, and neo-tectonic data suggests that existing models that involve recharge in eastern Australia, relatively simple flowpaths and discharge in springs in the western margin require modification. New geochemical data indicate a small volume flux of deeply derived (endogenic) fluids mixing into the aquifer system at a continental scale. Neo-tectonic data indicates active tectonism today that provides a fluid pathway through faults for the deeply sourced endogenic fluids to discharge in GAB travertine depositing springs.

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1. Introduction

The Great Artesian Basin (GAB) is one of the largest groundwater basins in the world and contains Australia's largest water resources (Figure 1, adapted from [1]). It is of international scientific importance as sustainable groundwater management is emerging as one of the global scientific challenges of the new millennium. Groundwater flow and storage has long been considered to occur in a continuous sand sheet

* Corresponding author. Tel +61-08-8201-2198.

E-Mail address: andy.love@flinders.edu.au.

like aquifer that underlies slightly over one fifth of the Australian continent. Under this previous scenario, groundwater travels up to 2000 km flow paths from recharge areas in eastern Australia with major discharge occurring along the southwest spring zone. While this model describes the hydrogeology in broad regional terms, it does not account for the complexity of the system, in particular faulting that provides conduits to a deep seated groundwater flow system. In this paper we examine new neo-tectonic data inferred from travertine dating using uranium series as well as noble gas data from bores and springs in the GAB.

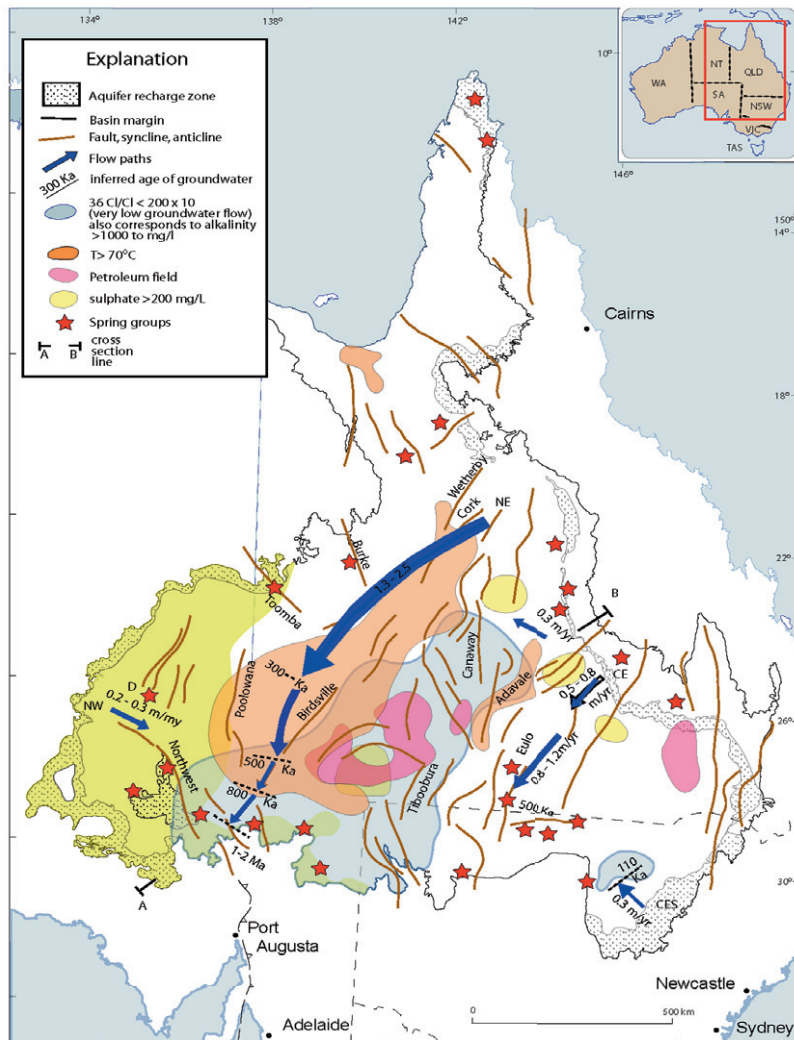


Fig. 1. Hydrogeochemical features of the Great Artesian Basin.

2. Geochemistry data

Geochemistry of water and gas in mound springs provides a window into groundwater mixing in the Great Artesian Basin (GAB). Elevated $^3\text{He}/^4\text{He}$ gas values, termed “xenowhiffs”, provide unequivocal evidence for small volume mantle-derived fluid sources that have been introduced into the groundwater system over the last several million years and hence document an active mantle-to-groundwater fluid linkage. Fluid and gas mixing is evaluated using multiple tracers. We estimate the external (deeply derived) CO_2 in water samples from both travertine mound springs and artesian bores using water chemistry and C isotope data. Contributions from dissolution of carbonate in the aquifer ($\text{C}_{\text{carb}} = \text{Ca} + \text{Mg} - \text{SO}_4$) is distinguished from contributions from biological/organic sources ($\delta^{13}\text{C} = -28\text{‰}$) versus mantle sources ($\delta^{13}\text{C} = -5\text{‰}$). Of the external C, mixing models using $\text{CO}_2/{}^3\text{He}$ values of 9×10^9 (Warburton Spring) to 2×10^{10} (Bubbler Spring) can be used to model contributions of CO_2 from the asthenospheric mantle (MORB end member taken as 2×10^9) versus lithosphere. Elevated $^{87}\text{Sr}/^{86}\text{Sr}$ values at Dalhousie Spring indicate fluid-rock interactions in granitic crust and small volume, but geochemically potent, crustal contributions to the endogenic fluids. Travertine-depositing springs are windows into active and heterogeneous groundwater mixing. Major element chemistry suggests different and highly variable water chemistry from spring to spring, different end member endogenic fluids, and variable mixing proportions in different sub basins. For example, western GAB springs are shown to fall into two hydrochemical facies (Dalhousie Springs and the CO_2 mound springs), each distinct from waters produced by ageing and slow transport of eastern Australian recharge waters. The travertine mound and platform rock record suggests the observed distinction between groundwater hydro-facies has been in place for at least about 650 ka, thus providing a link between the present paleohydrologic systems of the GAB. Hence, new models for the GAB require interactions between mantle and deep crustal fluid inputs, neotectonic pathways and groundwater mixing and segmentation within this continental scale artesian basin are required.

3. Travertine dating and neotectonics

The travertine deposits of the western Great Artesian Basin collectively provide a record that can be used to link the present hydrologic system to paleohydrology of the GAB. The travertine deposits are associated with mound springs (many still active) and form calcium carbonate precipitates due to CO_2 degassing as the highly carbonated groundwater emerges along faults. The travertine mound spring deposits also provide underutilized and sensitive gauges of neotectonics in Australia, one of the oldest, flattest, and least tectonically active of the continents. At a continental scale, the locus of mound spring discharge follows lithospheric zones of weakness (Tasman line and Torrens hinge zone). These were established in the Neoproterozoic but are currently being reactivated along the boundary between high velocity mantle in Western Australia and lower velocity mantle in eastern Australia, and as zones of concentrated micro-seismicity in the upper crust. At an intermediate scale, travertine deposits offer the potential to quantify rates and locations of neotectonic uplift/subsidence. They are located at the broad hinge region separating actively uplifting mountain ranges (Flinders and Dennison ranges) from subsiding areas (Lake Eyre).

Preliminary U-Series data provide age constraints on travertines. An age of 250 ± 4 ka from near the top of an elevated extinct travertine mound at Beresford Hill (base of travertine ~ 42 m elevation, sample ~ 53 m elevation) indicates rapid denudation rates (relative to the present ~ 16 m elevation of the Bulldog Shale surface) of 100–150 m/Ma likely driven by uplift. A U-Series date on the platform near Elizabeth Spring of 372 ± 14 ka (~ 34 m elevation relative to surrounding surface of ~ 14 m elevation) gives lower but still appreciable denudation rates of 54 m/Ma. Our hypothesis is that more comprehensive dating may show differential uplift depending on position relative to uplifting (west) versus subsiding (east) domains on either side of the mound springs hinge line. Collectively, the lowest elevations in the Australian

continent, the mound springs lineaments, and the resulting locations of the main discharge areas of the Great Artesian Basin are seen as a product of interacting scales of active tectonism. The U-Series dates indicate persistent deposition of travertine mound springs at discrete vent sites over hundreds of thousands of years. A second testable hypothesis is that times of largest travertine accumulations (10 - 20 ka, 120 ka, and 350 - 400 ka) may have corresponded to palaeowet times. Detailed records are also obtainable from travertine; a travertine sample that was growing inwards in a vertical crack-filling in a travertine platform several meters above the modern drainage near Sulphur Spring provides a potential paleoclimate record. Ages so far are $9,324 \pm 93$ yrs, $10,039 \pm 100$ yrs, $11,993 \pm 120$ yrs, $20,256 \pm 1,620$ yrs providing a detailed record of the transition into the Holocene. Stable isotope analyses of the dated travertines reveals that spring groups have different carbon isotope averages that may reflect local hydrology: all spring groups show striking temporal variations in oxygen isotope composition (ranging over 6 ‰), with synchronous variations seen in different spring groups. These results demonstrate that the extensive travertine deposits can be used to develop a climate record at both 100 ka and 1 ka time scales for comparison with other proxies - such as shorelines and speleotherms.

Understanding the relative importance of recharge and discharge rates is important when examining a large groundwater basin such as the GAB that is in a transient state. This work will provide proxy data to understand the relative magnitude and chronology of spring discharge through time, this will aid in the development of a transient conceptual groundwater model of the system.

4. Conclusions

These data show that new understanding of the GAB will require holistic models that merge hydrogeological, geochemical and tectonic perspectives with detailed hydrogeological models for fault geometry. Effective management of the GAB resource will require improved cooperation between the states and the federal government understanding complex flowpaths and water quality variations for effective allocation of water and preservation of springs.

Acknowledgements

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References

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